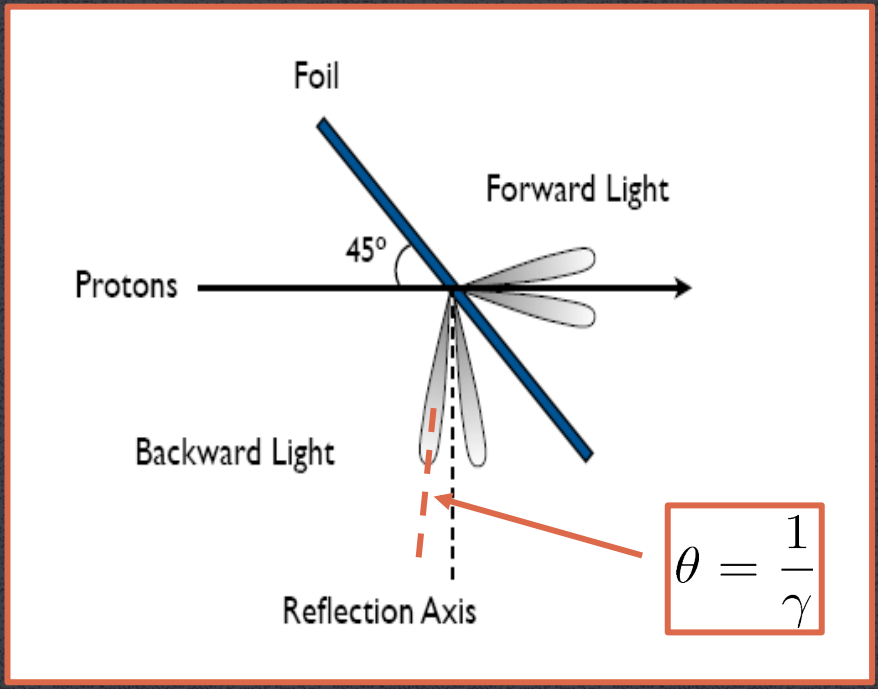
T2K OTR MONITOR

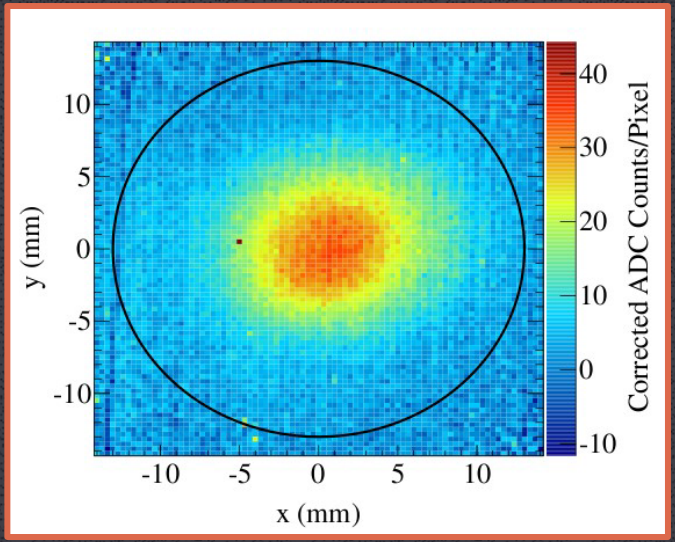
Proton beam position and width measurement
In front of neutrino production target

Why an OTR monitor?

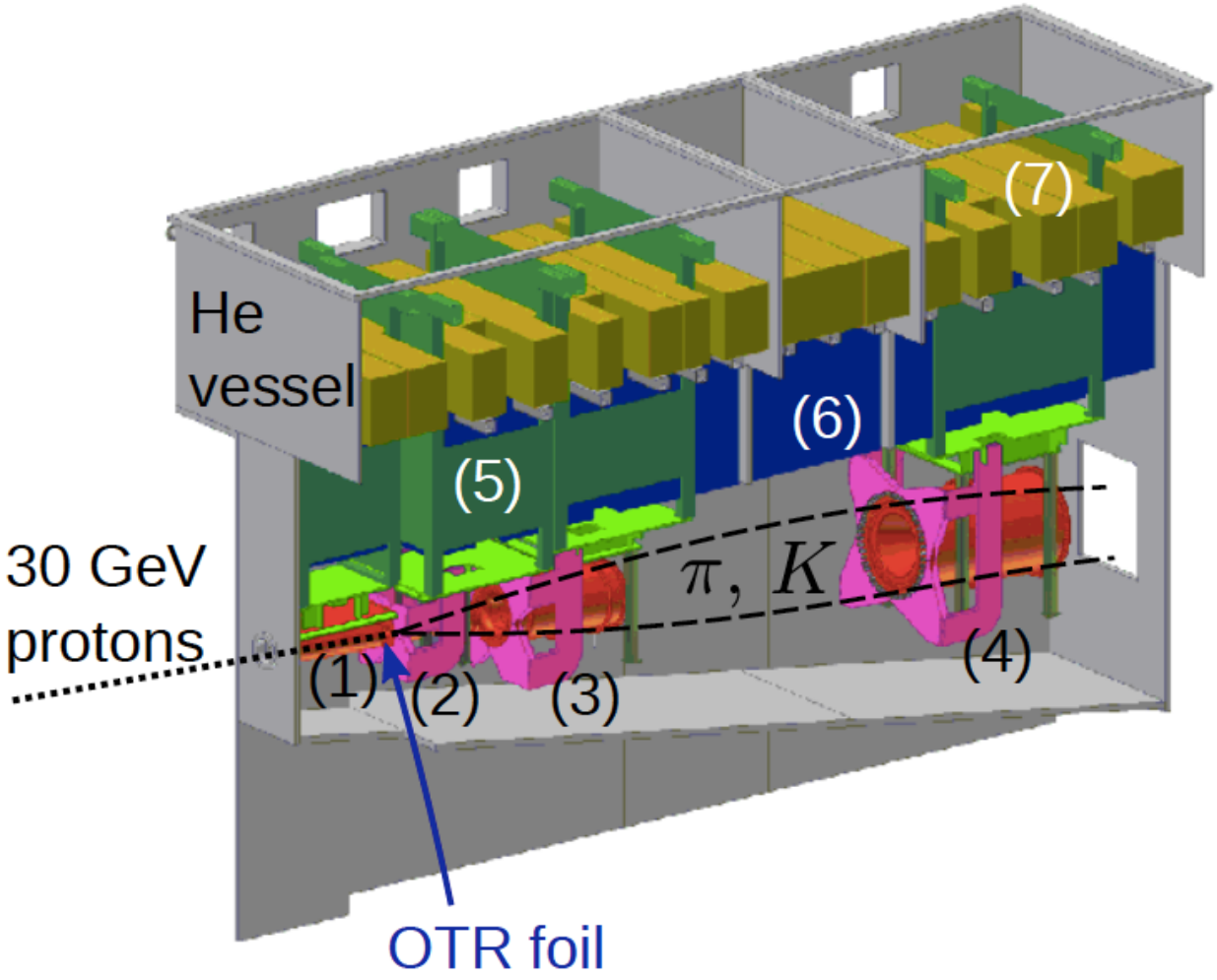
- physics systematics:
  - measure beam position at target to < 1mm
    - neutrino energy shift 2.2 MeV/mm
    - flux change 0.6%/mm
  - similar consideration for beam angle (require < 0.5mrad)
    - energy shift ~12 MeV/mrad
- target protection (450 → 750 → 1300 kW beam):
  - real-time monitoring
  - alert/abort for beam position and width changes
- titanium alloy foil can survive in beam (~5Sv/hr)
  - produces OTR light, transported far away to shielded camera by an imaging optical system

OTR


Foil
Forward Light
45°
Protons
Backward Light
Reflection Axis
$\theta = \frac{1}{\gamma}$


y (mm)
x (mm)
Corrected ADC Counts/Pixel
10
5
0
-5
-10
40
30
20
10
0
-10

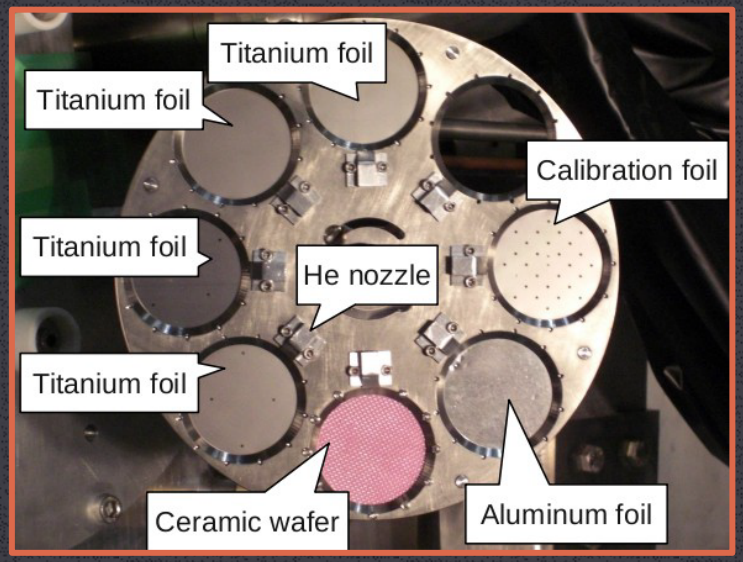
Target and horn focusing region inside He vessel

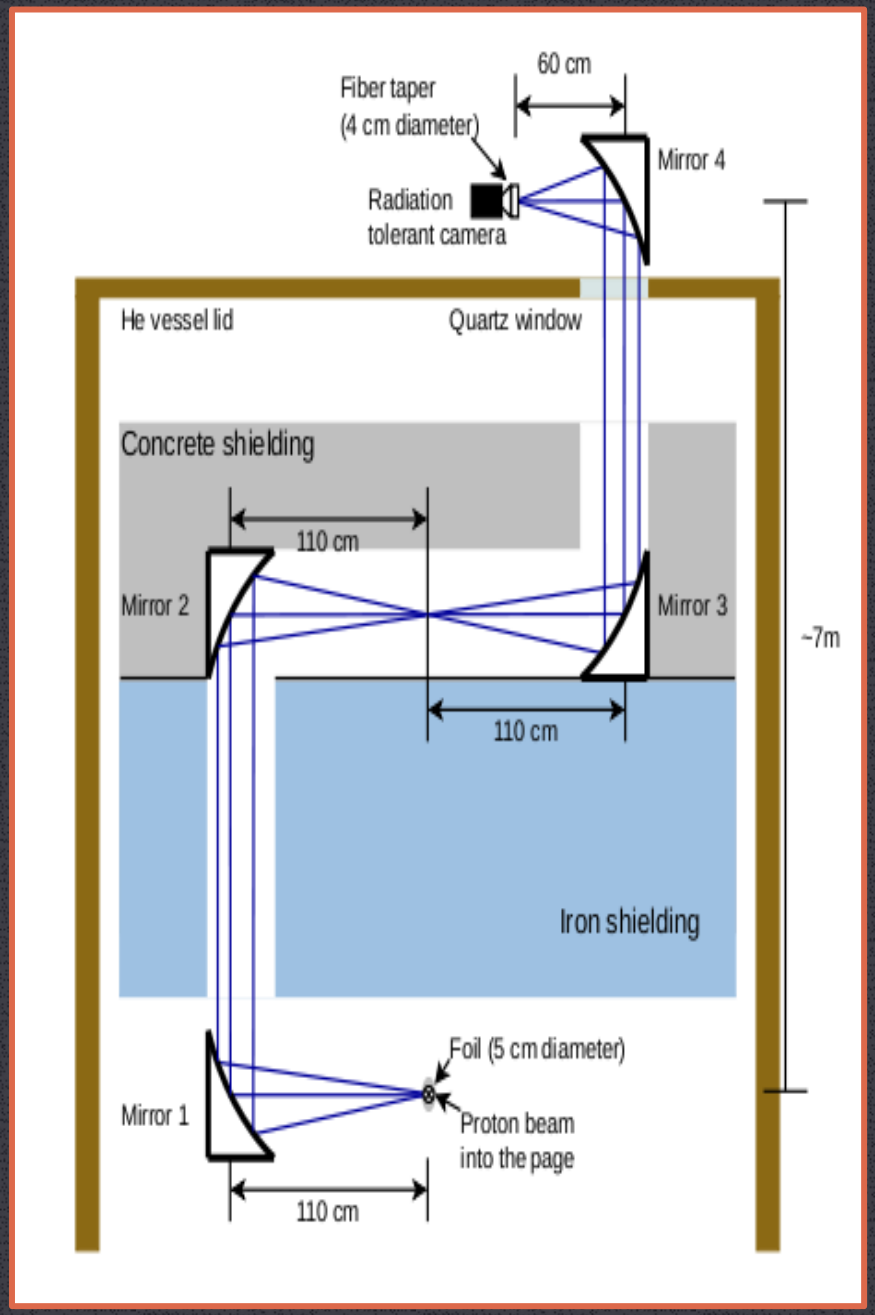


(1) Beam collimator
(2) First horn and target
(3) Second horn
(4) Third horn
(5) Support modules
(6) Iron shielding
(7) Concrete shielding

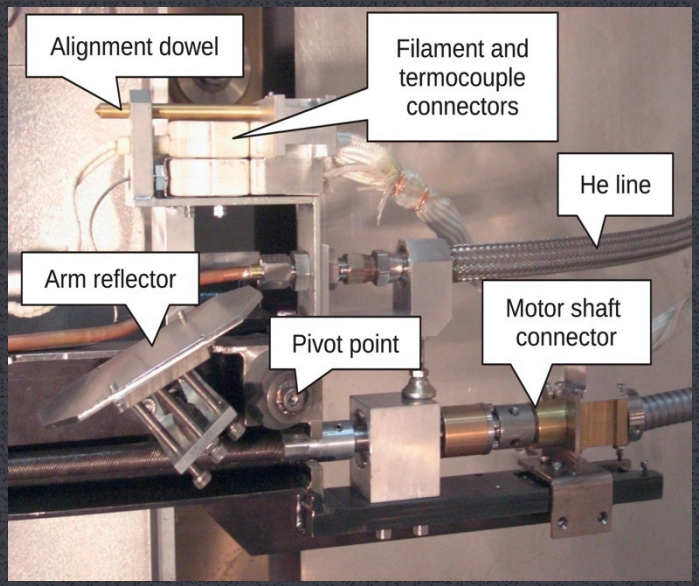
Layout

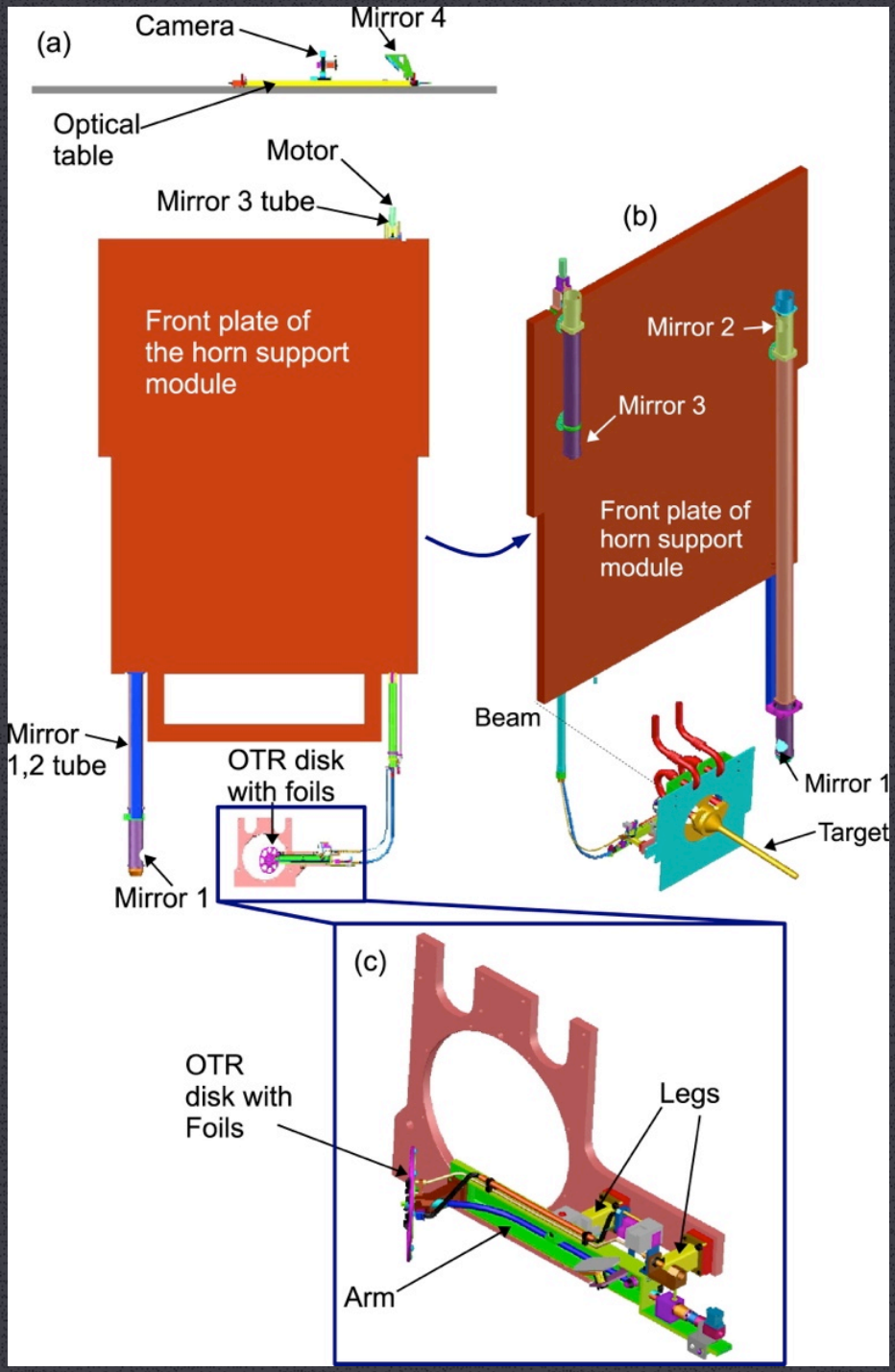
- 8 foil positions on rotating disk:
  - 1 ceramic – fluorescent light
  - 4 titanium – standard foils for OTR light
  - 1 aluminum – higher reflectivity than titanium foils
  - 1 calibration – machined hole pattern that is back-lit for calibration
  - 1 empty





OTR layout

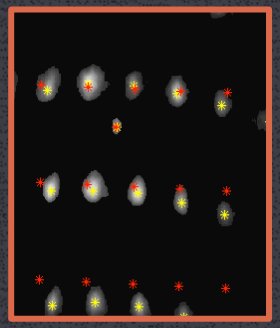

Alignment dowel
Filament and termocouple connectors
He line
Arm reflector
Pivot point
Motor shaft connector


(a)
Camera
Mirror 4
Optical table
Motor
Mirror 3 tube
Front plate of the horn support module
(b)
Mirror 2
Mirror 3
Front plate of horn support module
Beam
Mirror 1
Target
Mirror 1,2 tube
OTR disk with foils
Mirror 1
(c)
OTR disk with Foils
Legs
Arm

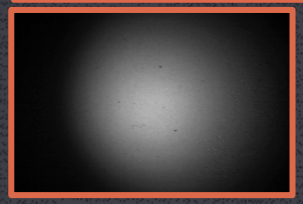
Calibration

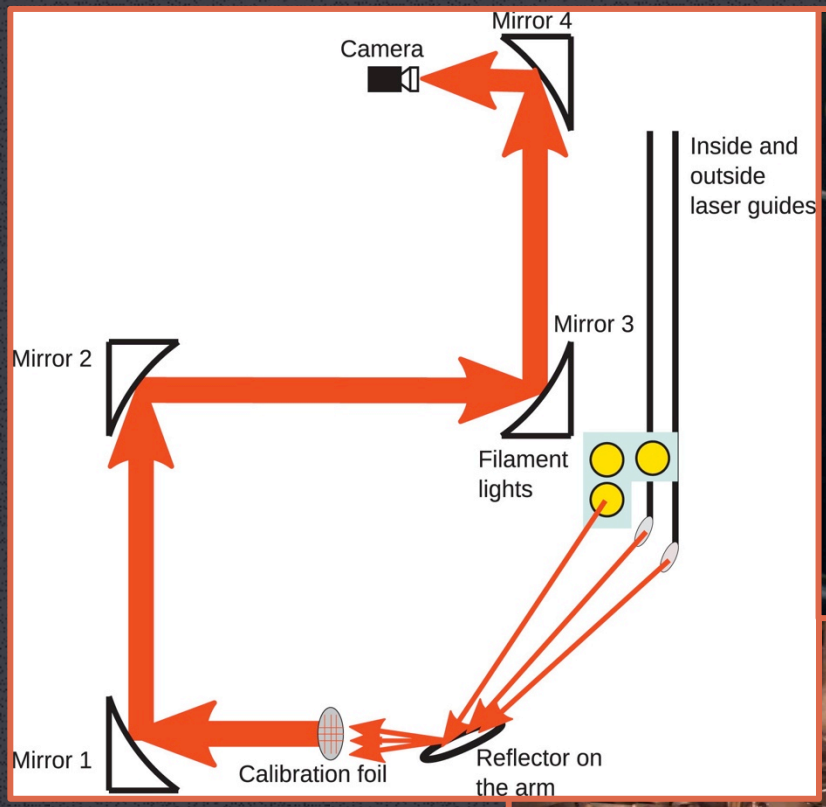
redundant light sources
- lasers, filament lamps

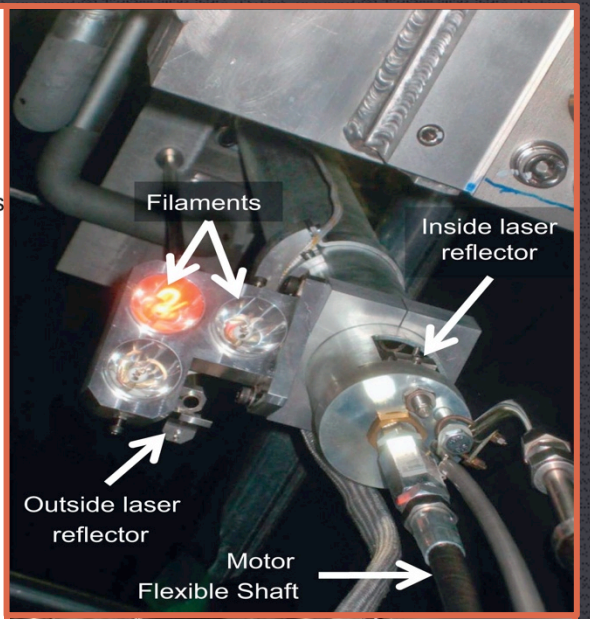
calibration images taken periodically to track calibration foil hole pattern:
- absolute position
- distortion corrections

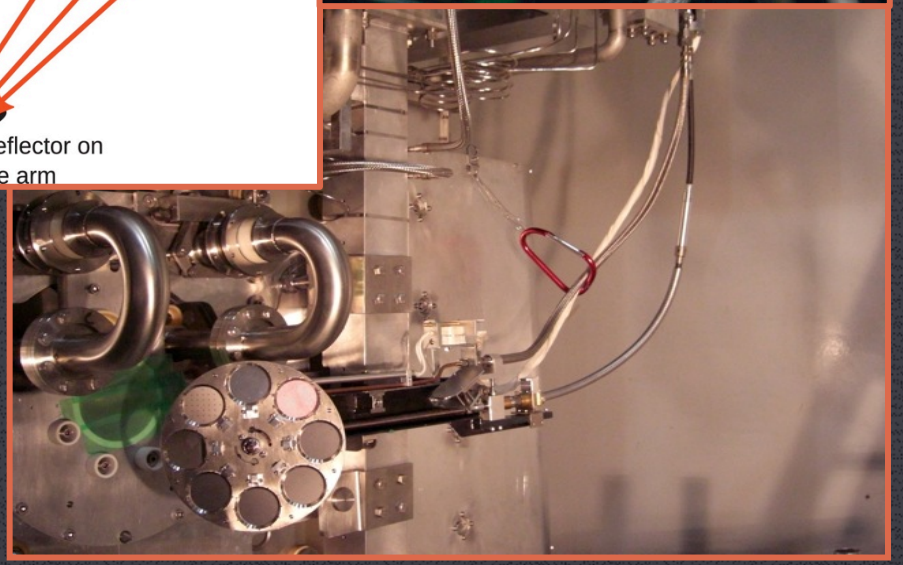


- efficiency map across acceptance from images with integrating sphere providing uniform light
- - tracked with images through the empty foil position





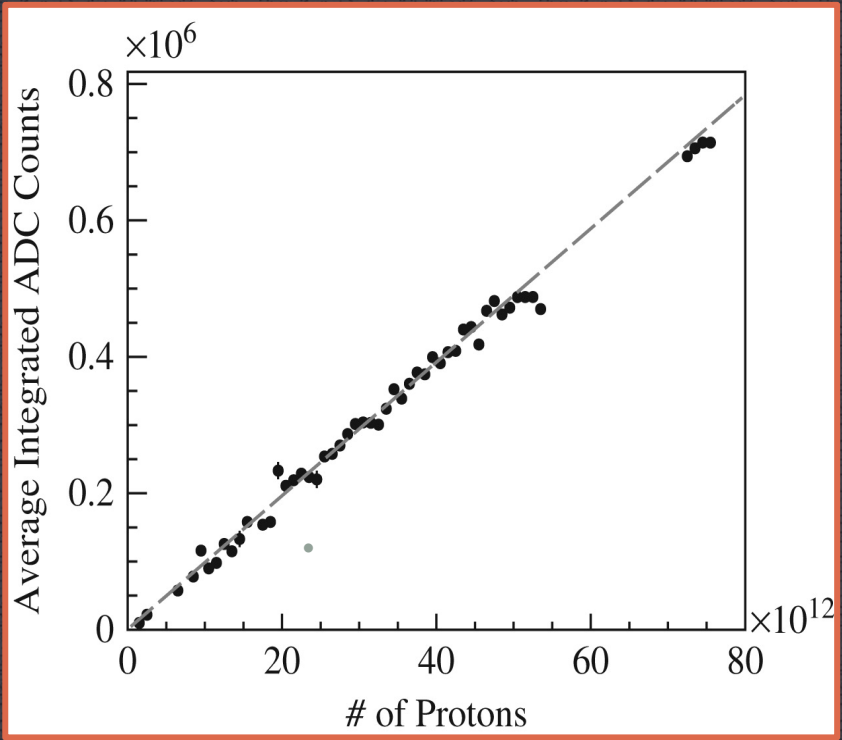




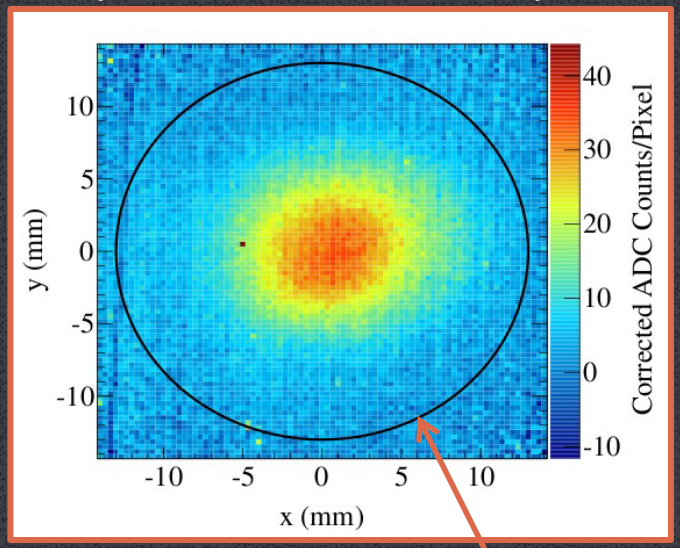
System has been remarkably stable!

Performance

- reliable operation during beam tuning and physics runs since 2009



OTR profile on Ti foil, 9 10^{13} protons



ELSEVIER

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Optical transition radiation monitor for the T2K experiment

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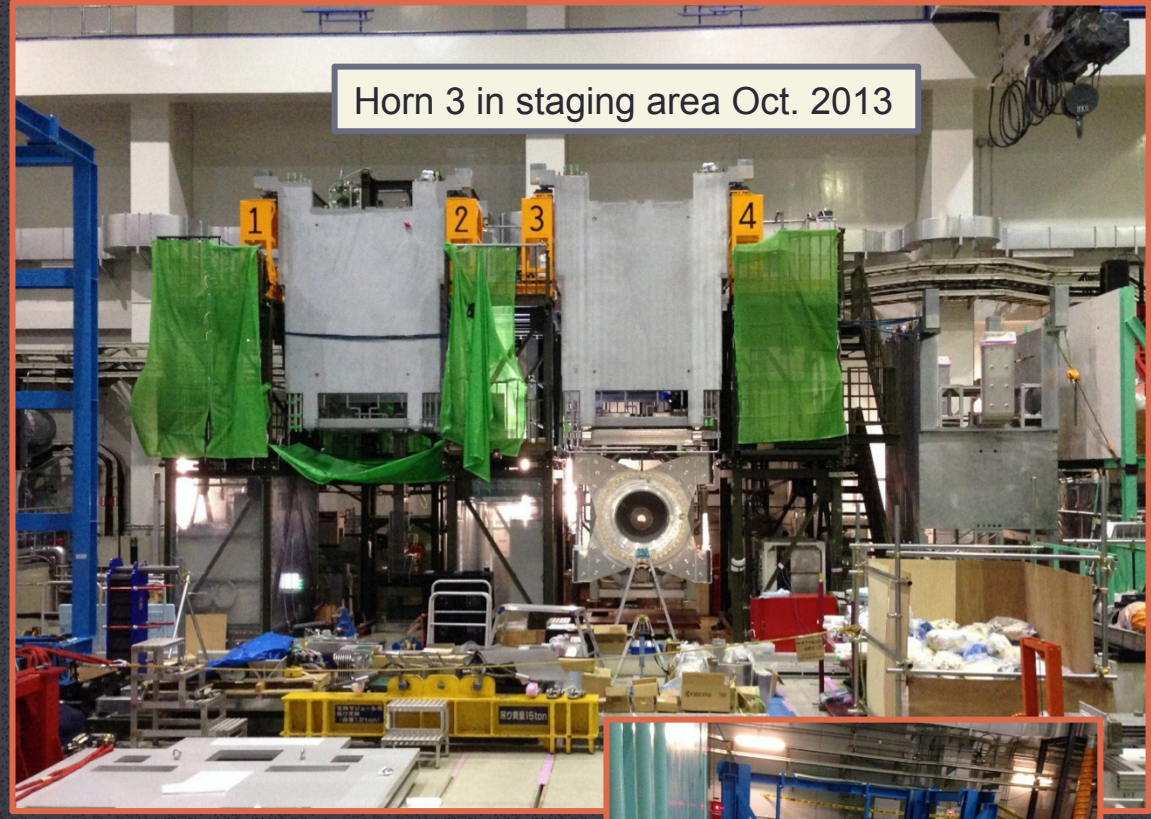
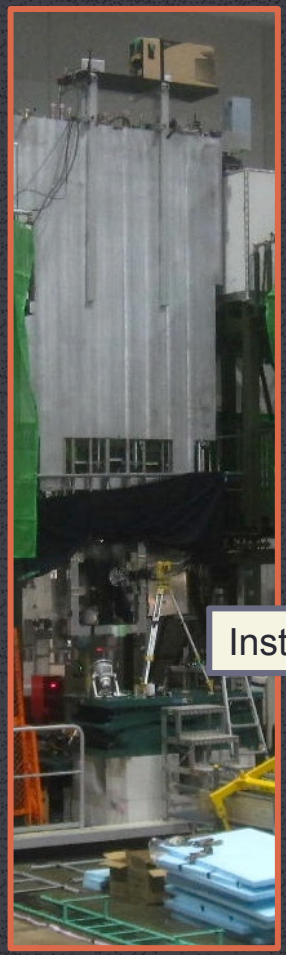
lowering a support module
with horn attached

Service pit

- possible to replace:
  - target
  - OTR disk and/or arm
  - horns

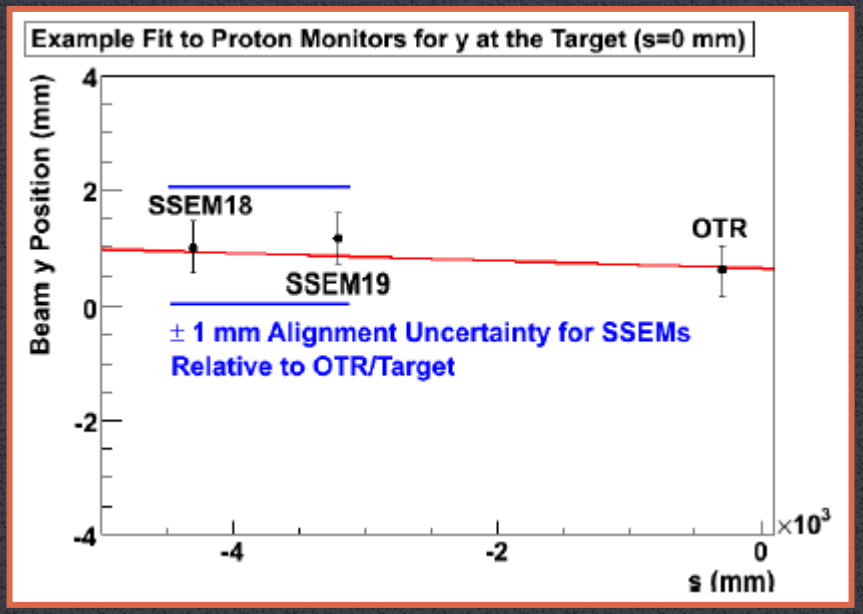
Commissioning





Installing and calibrating OTR-II February 2012

Impact of OTR on analysis



dominant uncertainty in beam position/angle is the vertical survey uncertainty (1 mm) and SSEM projection (>1 mrad)

- with OTR: $\delta y \sim 0.6$ mm and $\delta\theta_y \sim 0.3$ mrad (correlation ~0.4)

flux variation changing position and angle by 1 sigma (accounting for correlation)